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***NASA Ames Research Center***  
***ISS Utilization Research and Functionality Project***

**ARC EMCS PLANT BIOLOGY  
HARDWARE/PAYLOADS**

**ESA/N-USOC Topical Team Meeting**

**May 25, 2012**



# ARC EMCS Experiments

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## Background:

- NASA – ESA LOA/JIP/Barter Agreement being worked/in place since Sept 2001
- NASA supports NASA PIs, ESA supports ESA PIs
- NASA/ESA negotiate re resources (transport vehicle/ISS re mass, volume, power, etc.)
- NASA – one experiment per year in EMCS



## ARC EMCS Experiments

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### Completed NASA Experiments:

TROPI-1	Dr. John Z. Kiss Miami University Oxford, Ohio	2006
TROPI-2	Dr. John Z. Kiss Miami University Oxford, Ohio	2010

### Completed Ops but Samples still on ISS:

PLANT SIGNALING	Dr. Imara Perera North Carolina State University Raleigh, North Carolina	2011
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## ARC EMCS Experiments

- **Seedling Growth Experiments** are **different – combined** NASA/ESA Experiment
- The Seedling Growth series of flight experiments was taken from
  - ILSRA-2009-1177, PI: Dr. John Kiss, NASA
  - ILSRA-2009-0932, PI: F. Javier Medina, ESA
- Recommendation from NASA and ESA: PIs combine their studies to maximize the science returns from the flights.
- The combined experiments are divided into four parts (Seedling Growth-1, -2, -3, -4).
- The experiments are to be carried out in series. The first three flight experiments (Seedling Growth-1, -2 and -3) are designed to accomplish the specific aims enumerated in the proposals.
- The last flight experiment (Seedling Growth-4) is optional and will be used to confirm and/or extend the findings from the previous three flights.
- Seedling Growth-1 and -2 of the flight series are led by NASA in cooperation with ESA; Seedling Growth-3 and -4 ( -4 being optional) are led by ESA in cooperation with NASA.



# ARC EMCS Experiments

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## Current/Future NASA ARC EMCS Experiments

- Seedling Growth -1 (NASA Lead)
  - Barter: 100% NASA; ESA HW refurb/verification support
  - Launch SpaceX-2, Dec 2012
  - Return SpaceX-3, July 2013
- Seedling Growth -2 (NASA Lead)
  - Barter: 50/50% NASA/ESA resources
  - Launch SpaceX-4, Oct 2013
  - Return SpaceX-5, April 2014
- Seedling Growth -3 (ESA Lead)
  - Barter: 100% ESA; NASA HW procurement/refurb/verification support
  - FixBox for chemical preservation of samples;
    - ESA Development; NASA ARC procedure/HW support
  - Launch SpaceX-6, Aug 2014
  - Return SpaceX-7, Jan 2015
- Seedling Growth -4 (ESA Lead, TBD)



# ARC EMCS Experiments

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## ARC Personnel Contact Information

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## ARC EMCS Experiments



NON-PROPRIETARY

ESA T1 Mtg, N-USOC, M.Steele, May 2012





## ARC EMCS Experiments

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### We Don't Do It Alone

**Norwegian User Support Operations Center (N-USOC) – software schedules, commanding EMCS, Ground Tests in EM**

**MSFC – PIM, Crew Training, On Orbit Ops Scheduling (URC), On Orbit Operations Support, CoFR, CoCs**

**EADS/Astrium – Verification, final Flight Build Leak Check & Balance**

**JSC – Manifesting, Stowage – ambient, conditioned, Return Scenarios**

**KSC – Launch, Turn Over Support**

**European Space Agency (ESA)/NASA HQ – initial and ongoing negotiations)**





## ISS Facility - ESA

# EMCS

European modular cultivation system

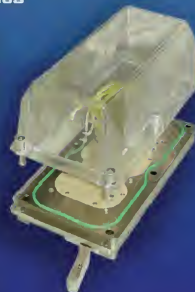


EMCS Holding Structure  
with Plant Rotor &  
Supply Modules

Experiment  
Container (EC)



Plant  
Rotor



LED Array



EMCS, developed by the European Space Agency (ESA), will provide long-term growth capability for plants in the International Space Station environment utilizing early flight opportunities. EMCS will be able to support multigeneration or seed-to-seed studies, and gravity-threshold, gravity perception, and signal transduction experiments. EMCS consists of an incubator (Holding Structure) with two centrifuges (600 mm diameter), both equipped with interfaces to four Experiment Containers (ECs) each, allowing cultivation in microgravity and acceleration at various g-levels.

Growth volume: 0.58 liter,  
60x60x160 mm / EC  
(4 ECs on each  
centrifuge)

Temperature control: 18° to 40°

Water/nutrient  
supply system

Relative humidity: 50 to 85%, controlled  
Light levels: ~300  $\mu\text{mol m}^{-2} \text{s}^{-1}$   
(LED arrays with  
white and red LEDs)

CO<sub>2</sub> level: 0.03 to 0.5% & 1 to 5%,  
controlled

O<sub>2</sub> level: 15 to 22%, controlled

Ethylene removal: below 0.01 ppm

Centrifuge: 10<sup>-3</sup> g to 2.0 g

Imaging: video cameras,  
tilting mirrors, frame  
grabber, IR dark  
observation

Downlink: data and video





# ARC EMCS Experiments

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## Hardware/Equipment on ISS

- European Modular Cultivation System (EMCS): ESA Facility;
  - Powered incubator
  - Control of atmospheric composition, temperature, and humidity
  - Two rotors with variable rotation speed (g levels)
  - Four Experiment Containers per rotor
  - Internal camera for imaging
  - data interface with the ECs
- MWA: workbench for the crew to process removal of the seed cassettes



# ARC EMCS Experiments

## Hardware

Experiment Container (EC) with  
ARC EUE and Seed Cassettes



### EUE:

- Hydration System (pump, bellows)
- Air Circulation System (air fan)
- LED lighting (white, red, blue)
- Circuit Boards (control of fan, lights, pump)



# ARC EMCS Experiments

## Hardware

### Seed Cassette with Seeds



### Seed Cassettes:

- Cover
  - Polycarbonate
  - Air Ventilation Holes
  - Gas Permeable Membrane/aluminum tape
  - Heater Film (top) to prevent condensation and allow imaging by EMCS camera
- Activated Charcoal Filter (not shown)
- Membranes with Seeds
- Base
  - Stainless Steel
  - Holes for Temperature Sensors
  - Holes for Hydration



# ARC EMCS Experiments

## Hardware

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### ARC Hardware Launched

#### 8 EMCS Cold Bags



### JSC Cold Stowage Hardware

- DOUBLE COLD BAG: passive, on orbit transfer of frozen samples from MELFI to GLACIER
- GLACIER: Powered transport of frozen samples back to Earth





# Seedling Growth-1

## Generic Operations

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### Experiment Flow

- Experiment must be started no later than 1.0 month after arrival at the ISS.
- Place ECs in EMCS on rotors.
- After the crew loads ECs into EMCS, the experiment run is initiated by ground commanding.
- Water for hydration of the seeds is stored in the EUE. Hydration is controlled by ground command.
- White growth light or red/blue light photo-stimulation is provided according to EMCS software schedules. The LEDs are part of ARC EUE.
- Digital images are captured at specific time points during growth and photo-stimulation periods according to EMCS software schedules and down linked.
- Samples (Seed Cassettes) are collected at the end of each 6-day run
  - Frozen and stored in MELFI
  - Chemically preserved and stored in TBD (SG-3 Capability)
- Return on SpaceX vehicle:
  - Frozen samples in GLACIER
  - ECs at ambient
  - Chemically preserved in TBD
- Images and samples turned over to PI

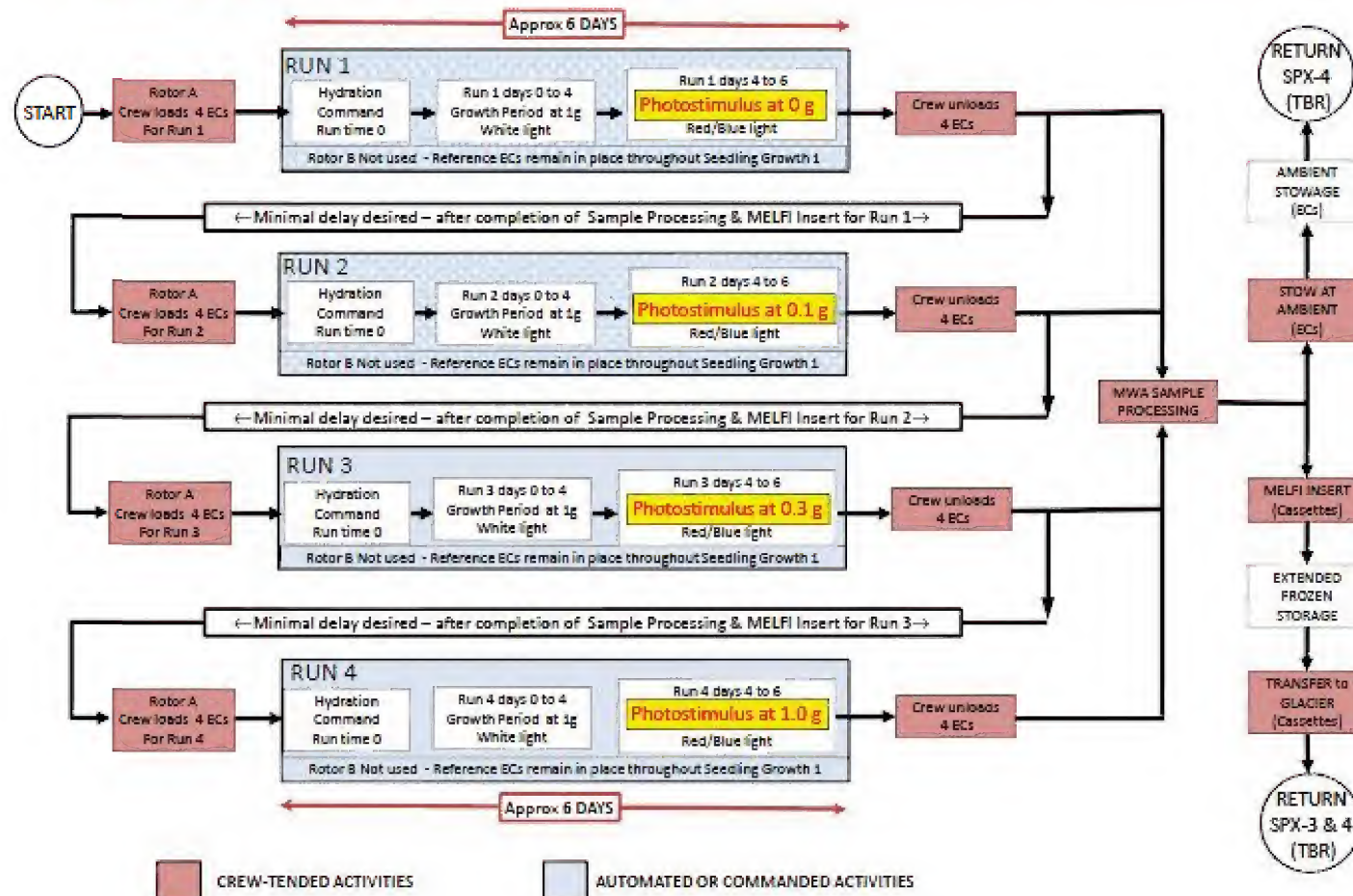
# Seedling Growth-1

## Example: Top-Level ISS Operations Timeline

### SEEDLING GROWTH-1: TOP-LEVEL EXPERIMENT FLOW

N1 9/22/2011

**NOTE:** The 4, six-day runs shown here use the same total resources as agreed at the NASA/ESA Phase A review of March 2011 for 2, 12-day staggered runs. This is a nomenclatural change only.

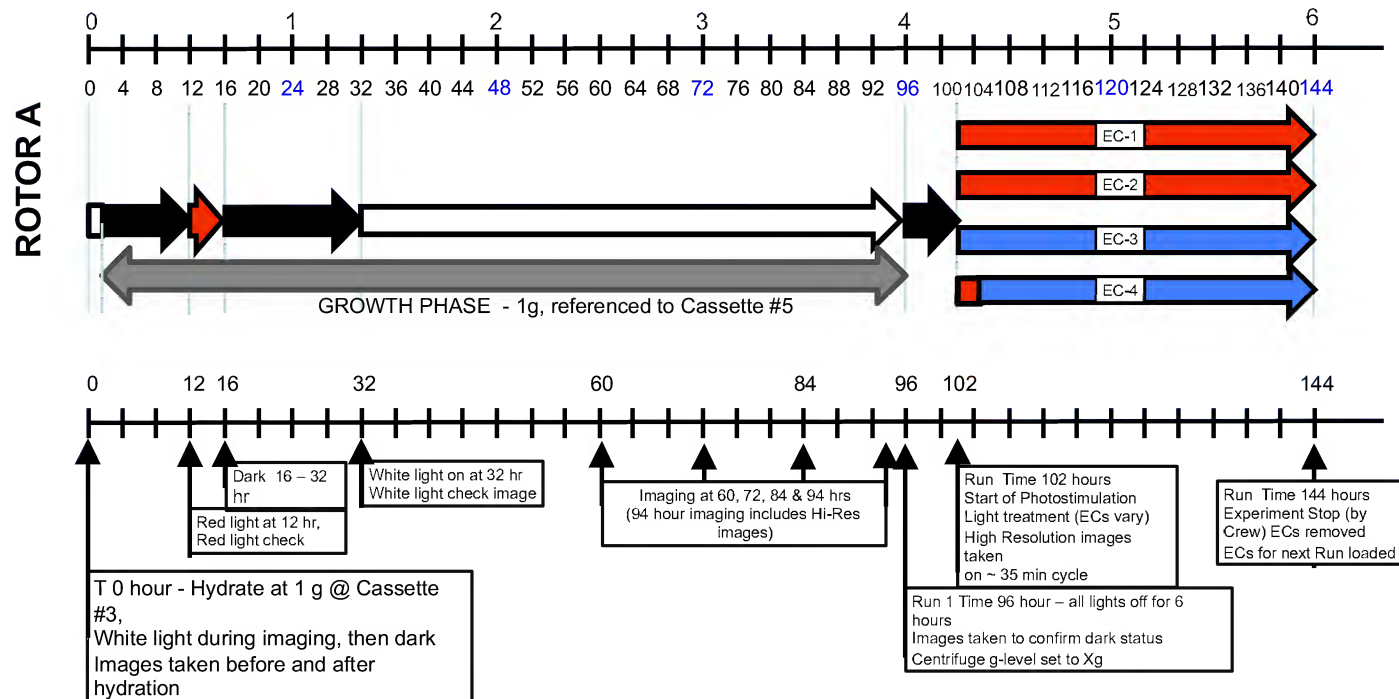






## ARC EMCS Experiments

### Kiss Timeline TROPI 1 & 2, Seedling Growth 1 & 2



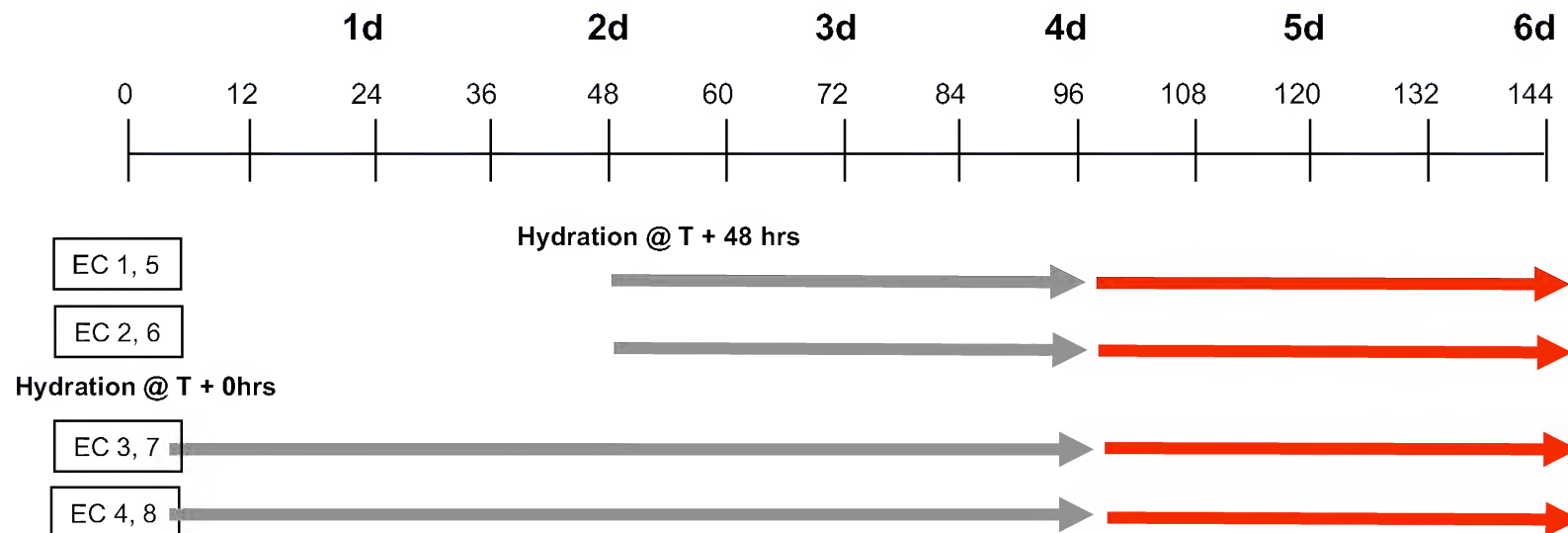
**ROTOR B** unused throughout – Reference ECs in place on rotor

g levels: 0, 0.1, 0.3, 0.5, or 0.8 during photostimulation



## ARC EMCS Experiments

### Medina Timeline Seedling Growth-2

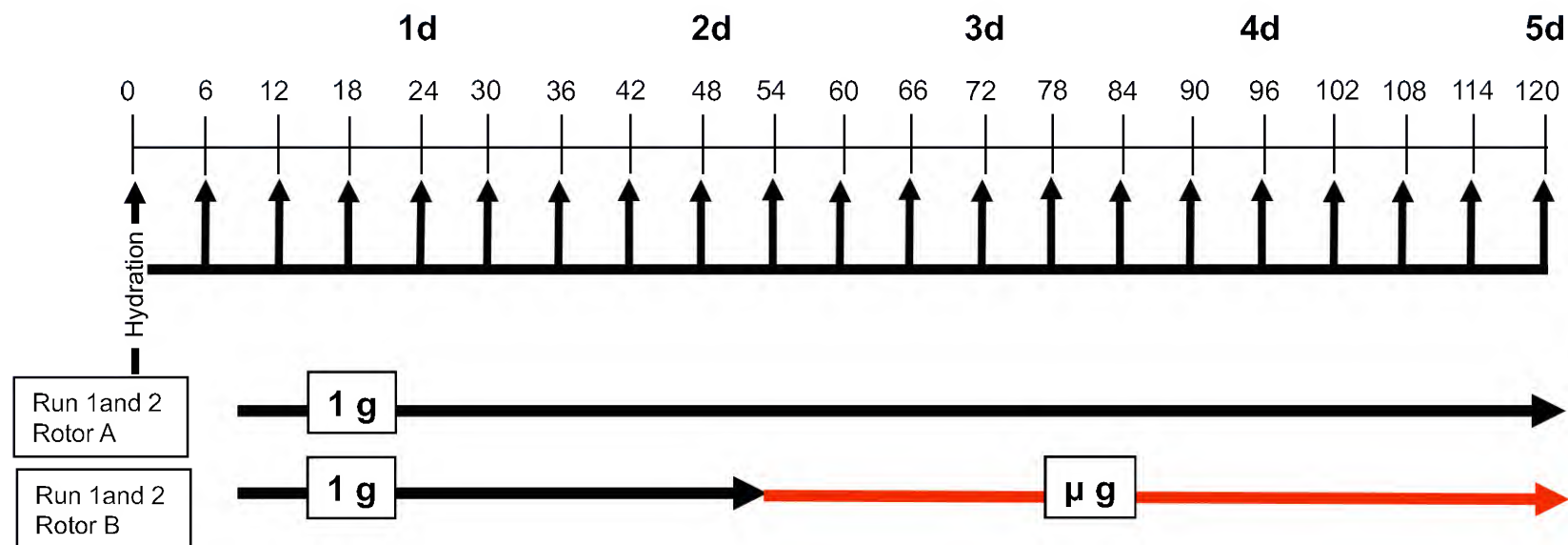


Generic Time Line as per F. J. Medina requirements in ESA ESR  
Rotor A, EC 1 – 4, Continuous Microgravity; Hydration @ 1.0 g  
Rotor B, EC 5 – 8, Continuous 1.0 g  
Grey = 24 hr Light Cycle: 16 hrs White LEDs, 8 hrs dark  
Red = Continuous Red Photo-stimulation LEDs



## ARC EMCS Experiments

### Perera Plant Signaling Experiment Timeline



For all Runs and Rotors @ "1.0g" = 1.0 g Set Point @ SC 5 (outer edge of rotor)



## ARC EMCS Experiments

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### Future NASA ARC EMCS Experiments beyond Seedling Growth TBD

Dependent upon:

- Budgets
- PI selection from NRA and/or ILSRA
- NASA/ESA Barter Agreement



## Seed Cassette images taken during the Plant Signaling Experiment on the ISS July 2011

